OAK RIDGE National Laboratory

Secondary Use Multi-Chemistry System Development

2021 DOE OFFICE OF ELECTRICITY ENERGY STORAGE PROGRAM ANNUAL PEER REVIEW

October 28, 2021

Madhu Chinthavali
Power Electronics Systems Integration Lead

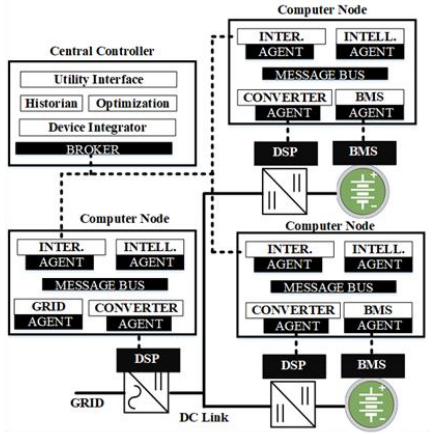
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

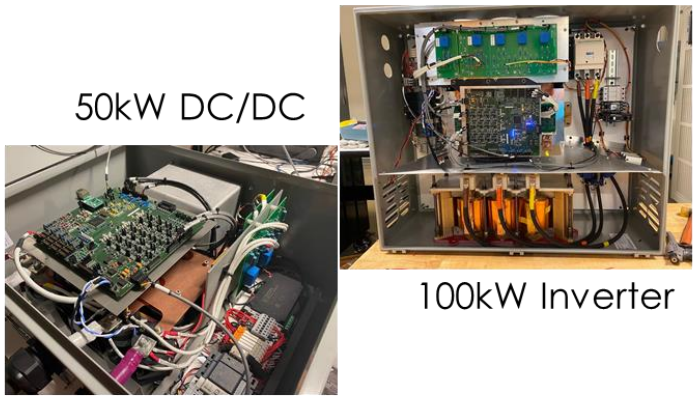
U.S. DEPARTMENT OF ENERGY

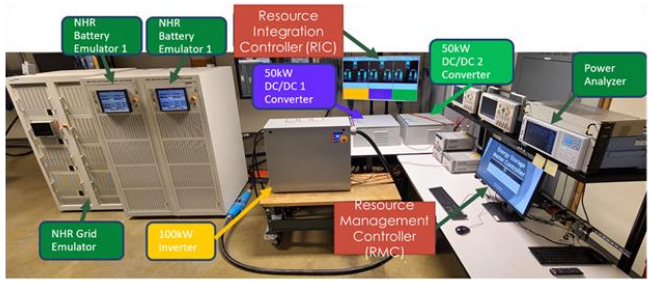
Project Overview

Objective : Drive **industry acceptance** by solving the challenges of integrating multiple **secondary use energy storage systems** developing additional features, increased functionality and **demonstrating** the technology

Overall Approach :

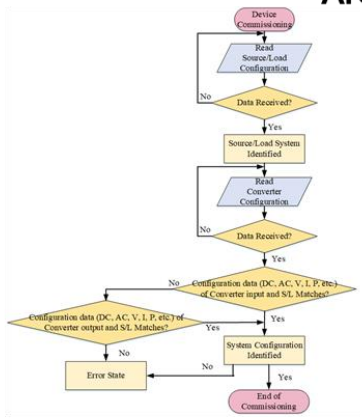






Initial Design

Software Architecture

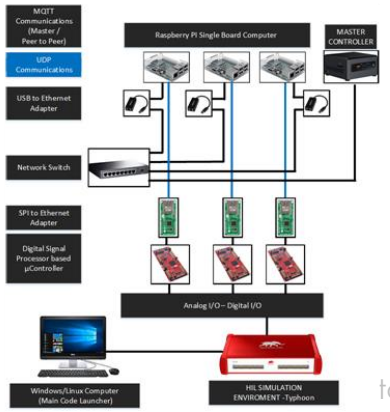


Hardware Design& Prototyping

Software Development

Controller-Hardware In the Loop

System Validation



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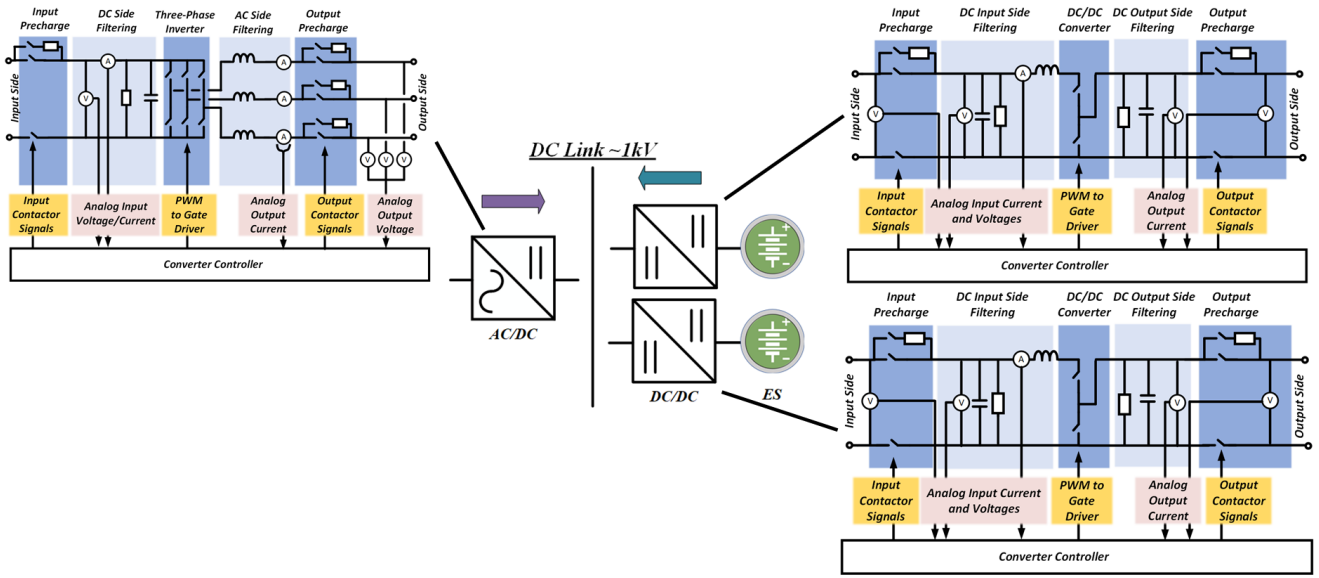
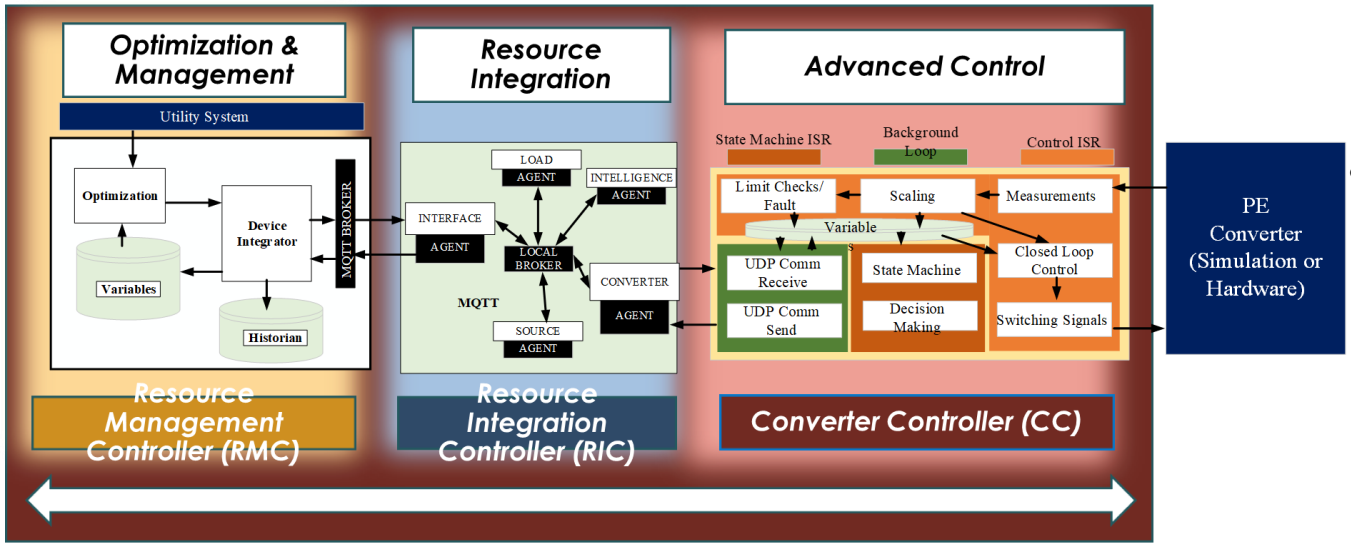
Software Framework Development and Validation

Multi-Chemistry / Energy Storage PE System



Control and Optimization using Distributed Agent-based System (CODAS)

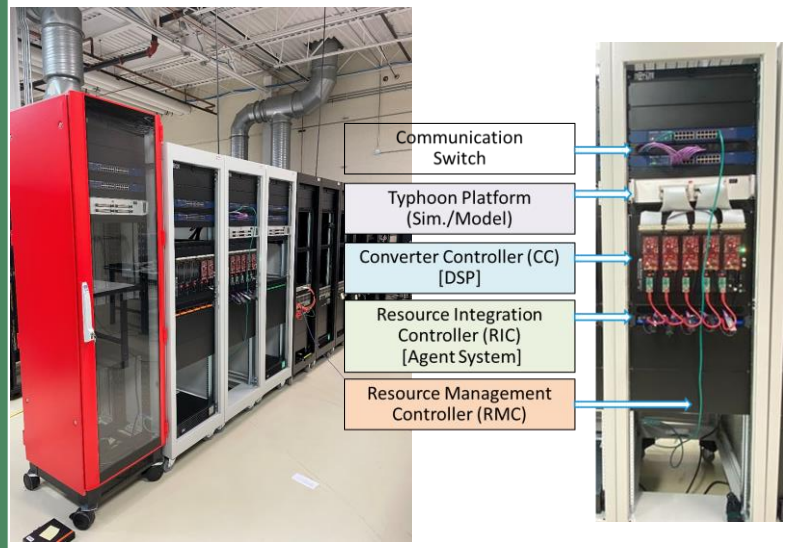
Developed to support power electronic systems integration for both simulation and hardware projects

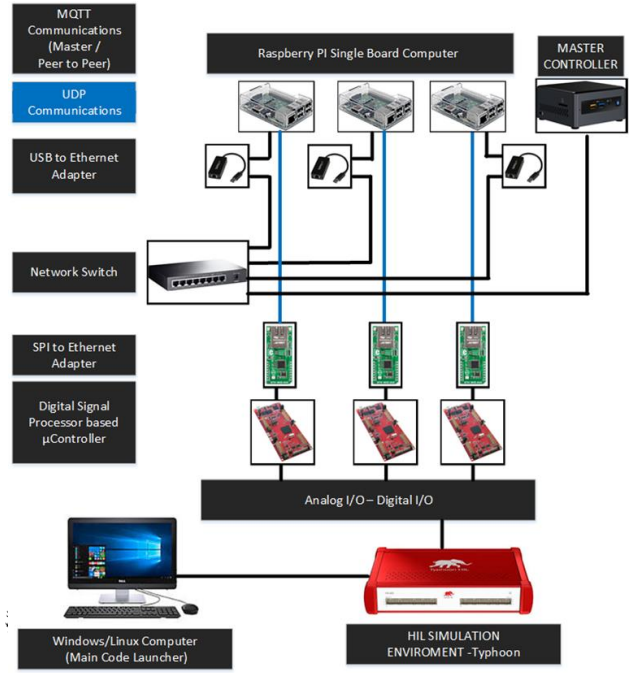


- 100 kW system with two 50 kW DC-DC for **multiple secondary use systems** with different chemistries and ages.
- Additional features and increased functionality and demonstrating technology with best practices including FMEA development.
- Same controller hardware and communication framework as applied to hardware testing.
- Used in early development stages to verify stability of optimization, controls, communications, and systems integration.
- All hardware systems are modeled including pre-charge and contactor circuitry to ensure start-up and shutdown sequences and protection systems are validated.

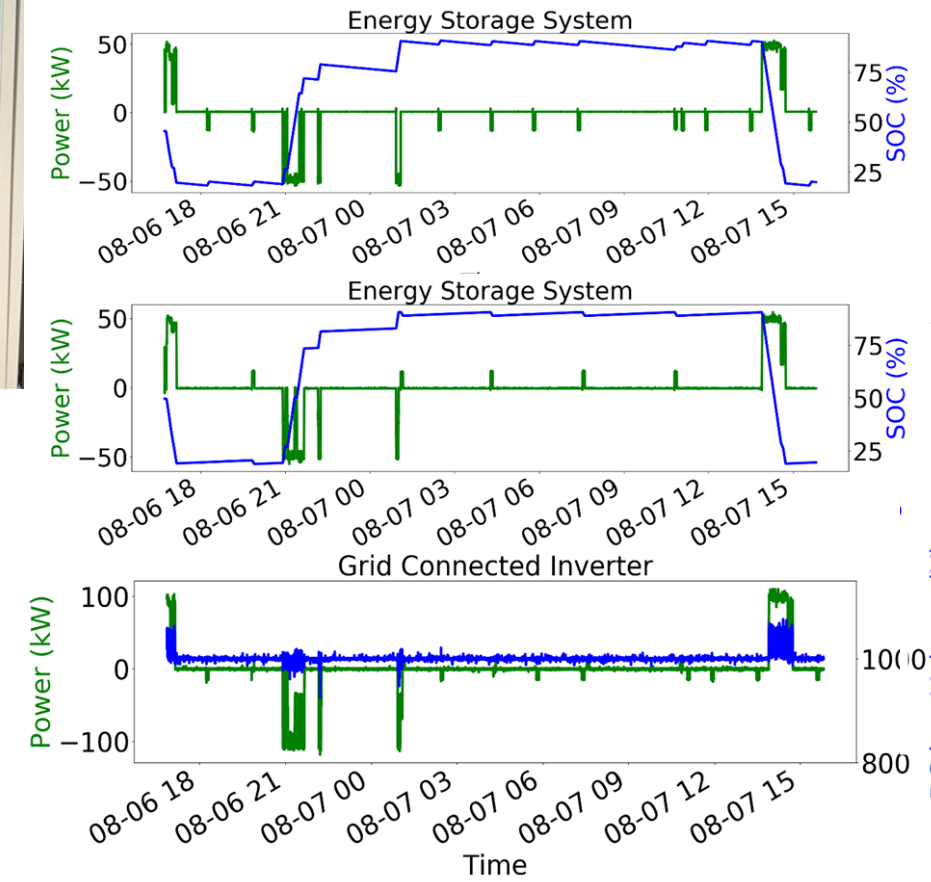
Software Framework Development and Validation

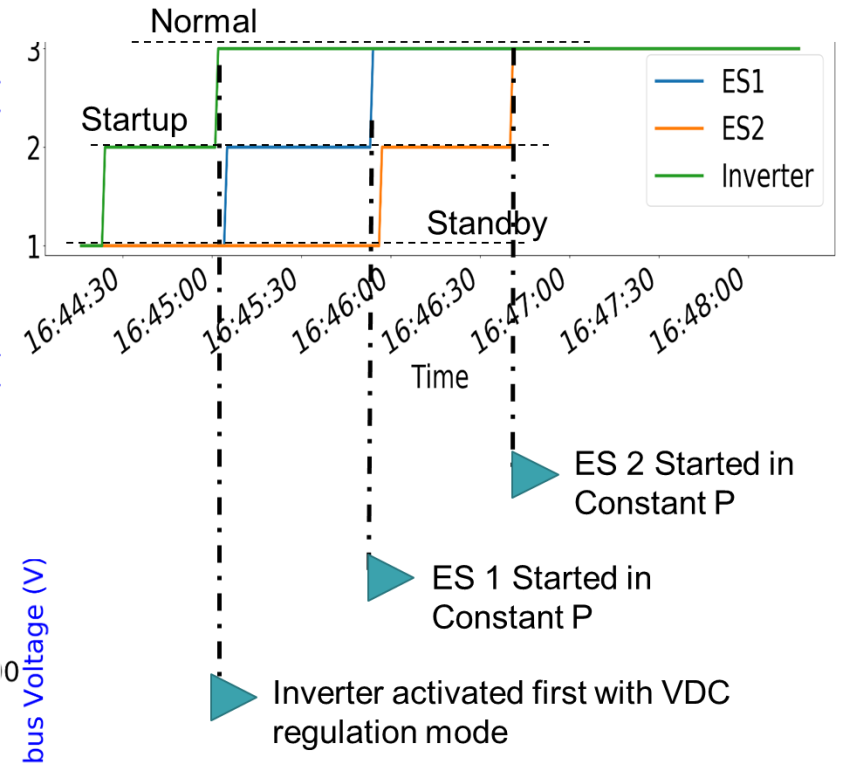
CHIL Validation in GRID-C @ORNL



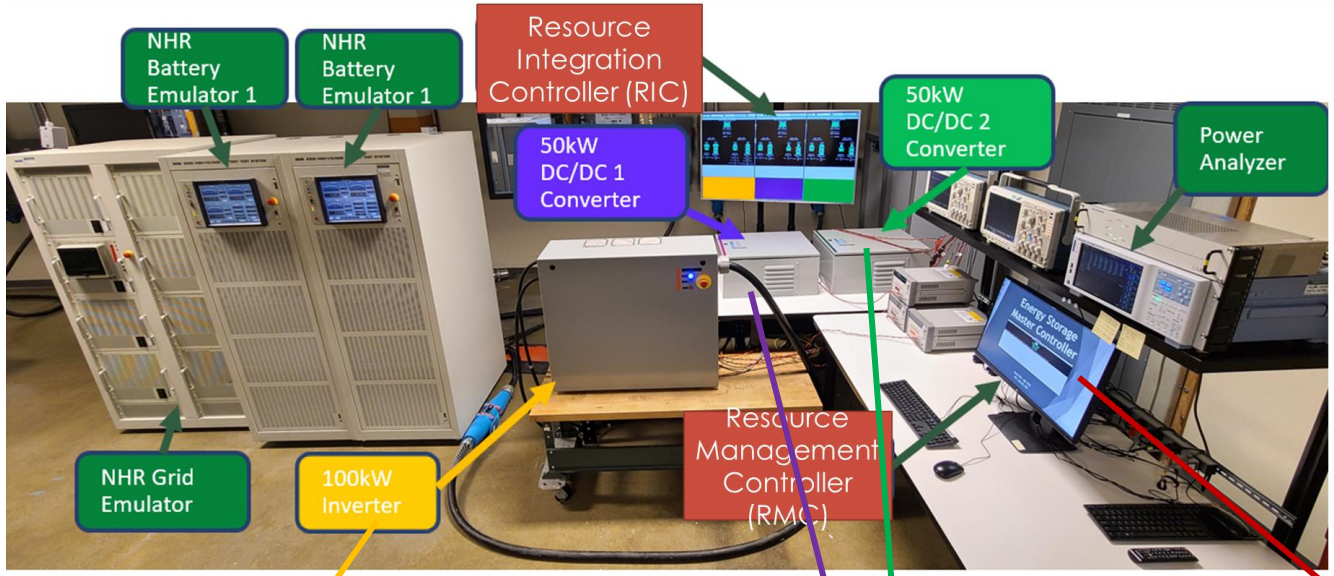


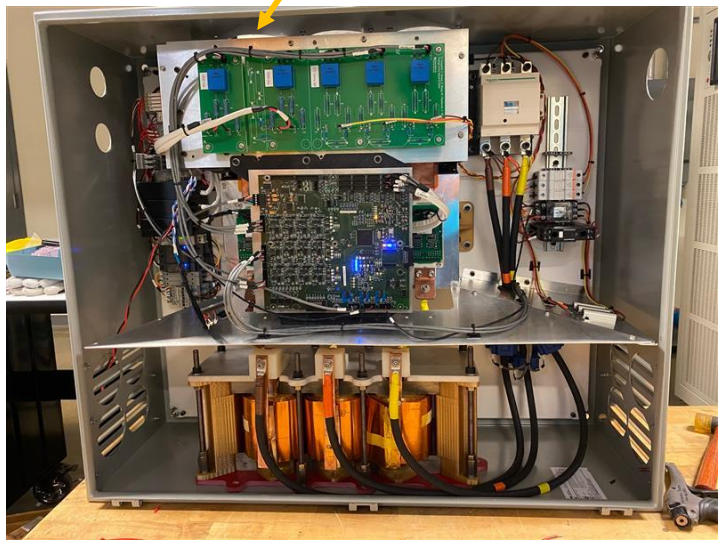
Validation of Software architecture and Controller Hardware - 24- Hour Simulations runs



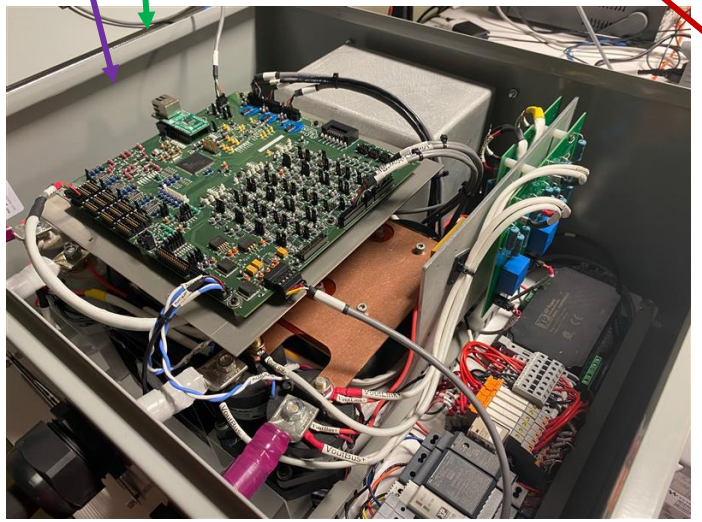


Integrated Full System Testbed in Grid-C- Steady state Operation

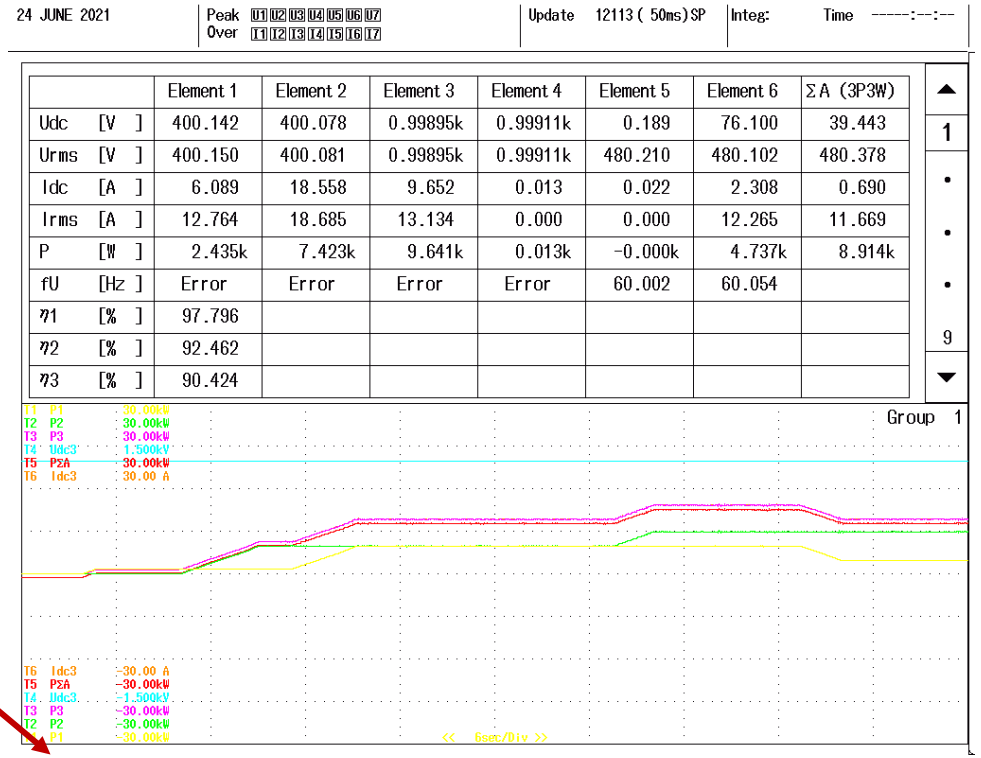


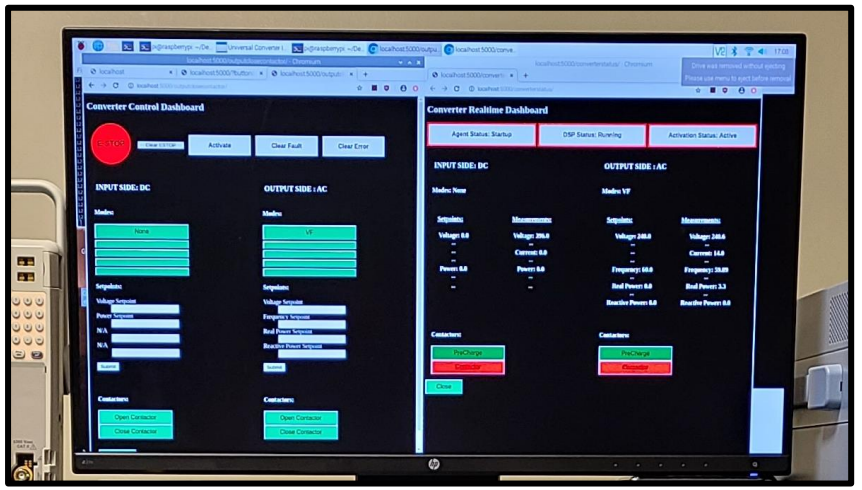


ORNL Developed 100 kW Inverter



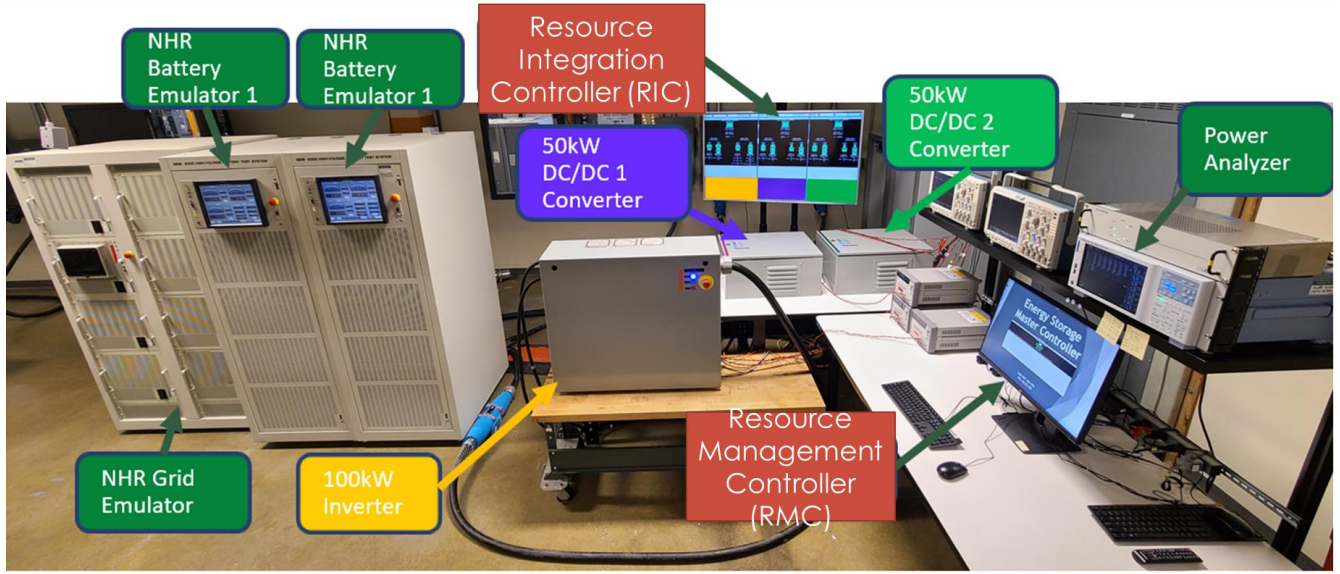
ORNL Developed 50 kW DC-DC

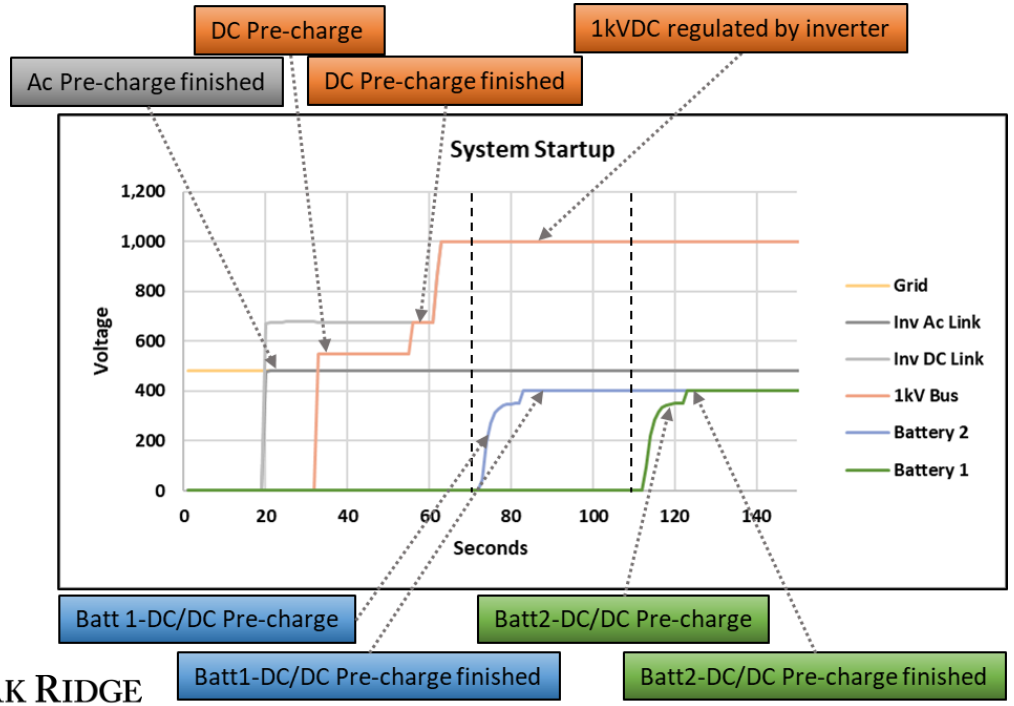


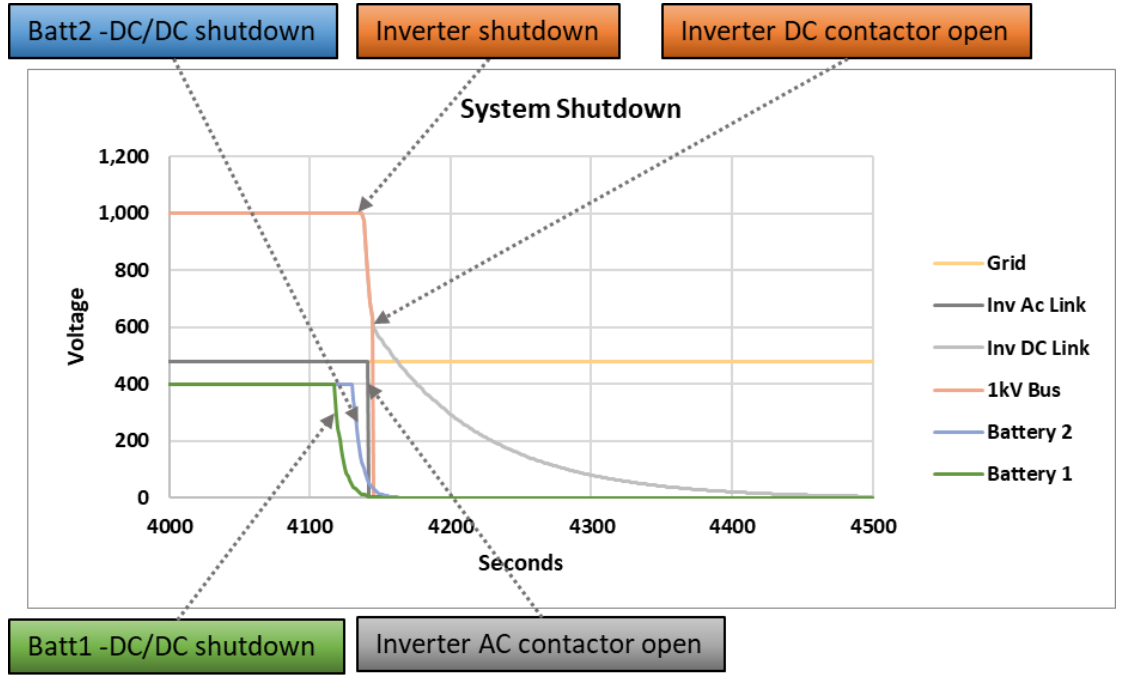


ORNL Developed Software Interface

Integrated Full System Testbed in Grid-C- Transient Operation







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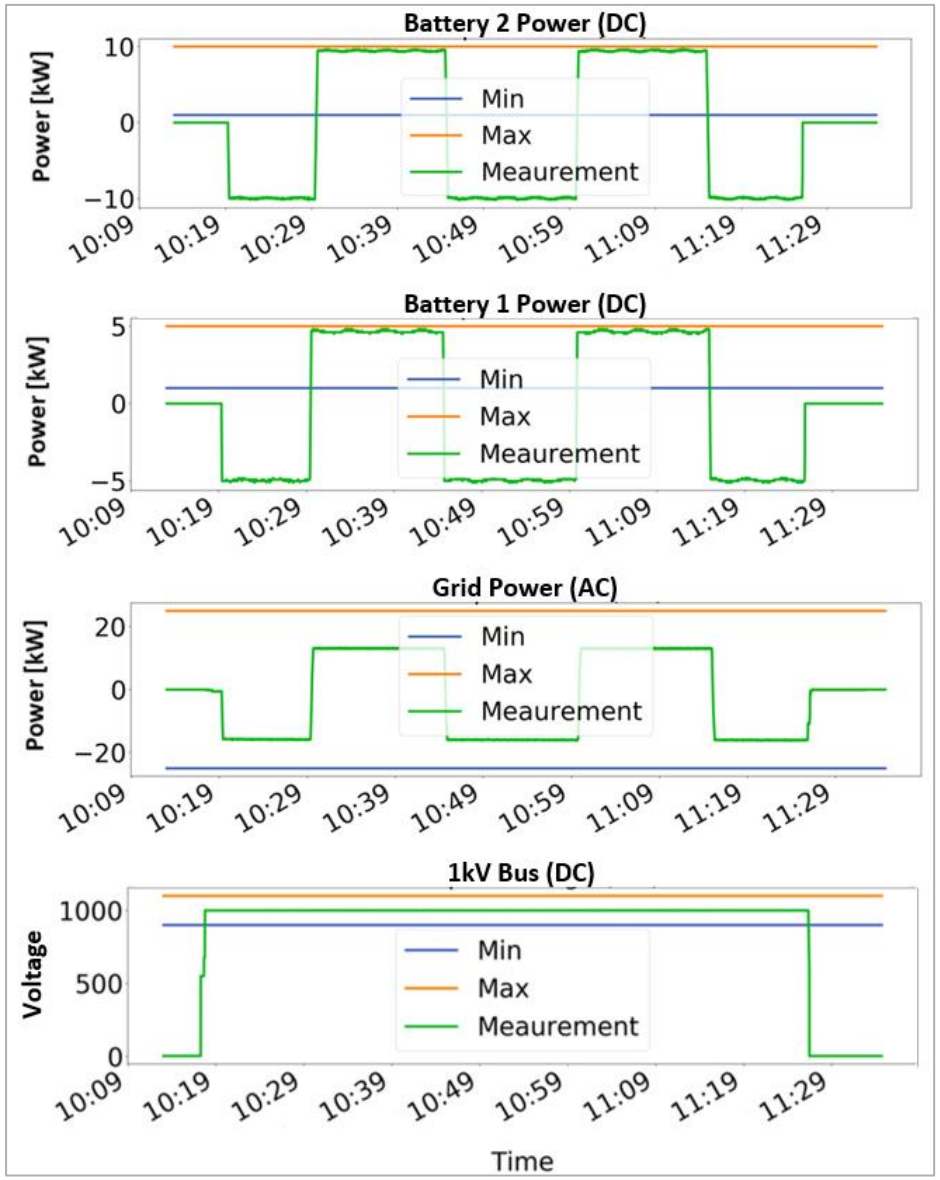
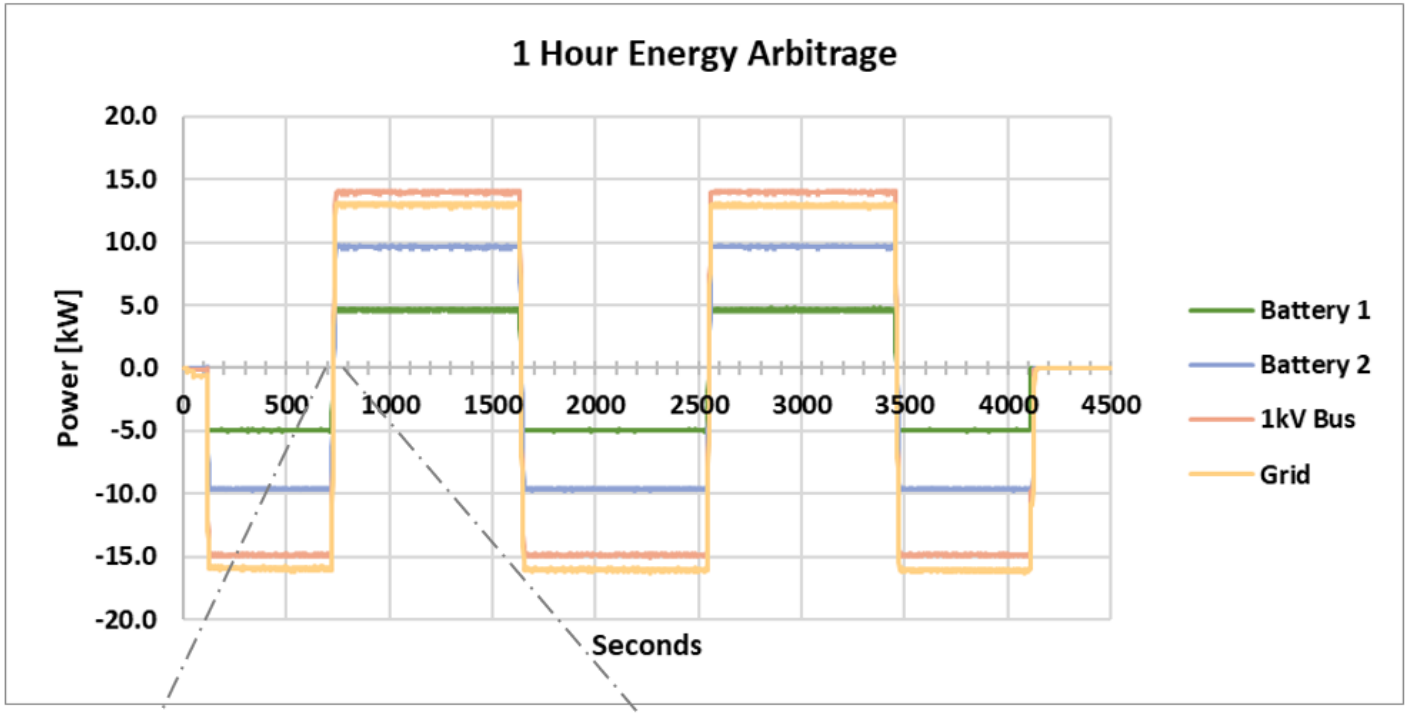
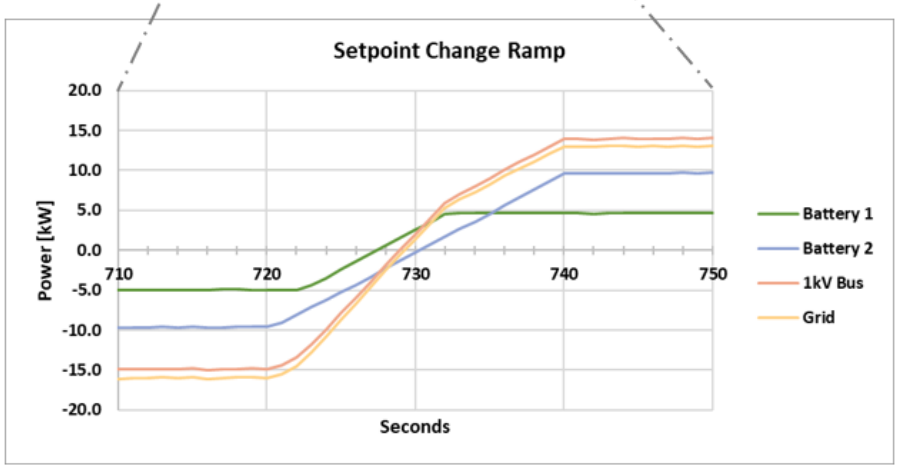
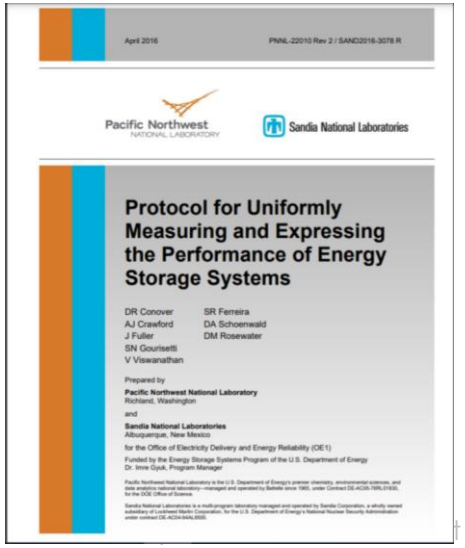
Energy Storage System Use Case Validation: Energy Arbitrage









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Accomplishments:

- **Completed the integration of multiple DC/DC and AC/DC power electronics systems**
- **Completed the integration of the software agent interfaces and the master controller with the system hardware**
- **Validated the transient and steady state operation of the full energy storage system with optimization**
- **Completed the energy arbitrage use case, advanced control modes to be integrated.**
- **One Journal and three Conference papers published**

- M. Starke, M. Smith, B. Xiao, A. Thapa, S. Campbell, P. Bhowdin, R. Moorthy, A Remote Development Process for Power Electronic Systems," IEEE Energy Conversion Congress and Expo, 2021.
- M. Starke, P. Bhowdin, S. Campbell, M. Chinthavali, B. Dean, R. Moorthy, M. Smith, A. Thapa, B. Xiao, Agent-Based Power Electronic Systems for Supporting Intelligence at the Grid Edge, IEEE Journal of Emerging and Selected Topics in Industrial Electronics, 2021.
- Michael Starke, Pankaj Bhowmik, Bailu Xiao, Radha Sree Krishna Moorthy, Steven Campbell, Ben Dean, Anup Thapa, Madhu Chinthavali, A Secondary Use – Plug-and-Play Energy Storage System Composed of Multiple Energy Storage Technologies, IEEE Innovative Smart Grid Technologies, February 2021.
- Benjamin Dean, Michael Starke, Madhu Chinthavli, Mitchell Smith, Leon Tolbert, A Communication Testbed for Testing Power Electronic Agent Systems, IEEE Innovative Smart Grid Technologies, February 2021.

Future Work and Acknowledgments

Future Work:

- Long-term Testing and Use Case Evaluation
- Deployment and Long-term testing Opportunities
- Utilize the system to support field issues in collaboration with partners
- Through CEDS program, looking at Cyber Security Interfaces
- Continue to work on publications

Acknowledgments

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Team

Madhu Chinthavali, PhD
Power Electronics Architecture

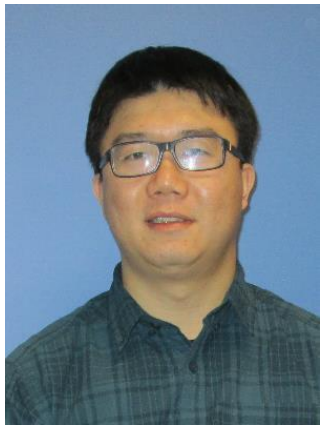
Michael Starke, PhD
Systems and Software Architect

Steven Campbell
Systems Integration and Evaluation

Brian Rowden, PhD
Hardware Architect

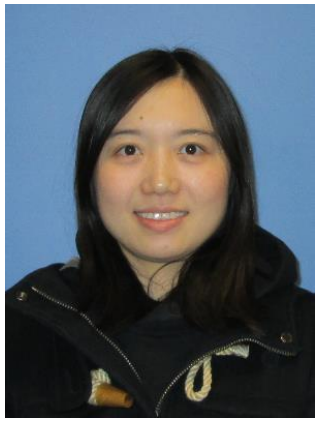
Rafal Wojda, PhD
Magnetics

Christian Boone
Mechanical CAD architect



Sheng Zheng, PhD
Power Electronics system Integration

Radha Moorthy, PhD
Communications and Controls



Bailu Xiao, PhD
Software and Agent Systems

Anup Thapa
Imbedded Hardware Control

Pankaj Bhowmik, PhD
CHIL Evaluation